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"WHEN THE MOON RUNS HIGHEST AND RUNS LOWEST."

BY ROSE O'HALLORAN,
Member A. S. P.

Though subject to the unbending rule of solar and terrestrial attraction, the path of the Earth's satellite is no cast-iron groove on the highway of the heavens. Within the boundaries of a zone extending nearly six degrees on each side of the ecliptic, or Sun's path, her sway is complete; and every star in the allotted realm is, sooner or later, blotted out of view by her intervening disk. Even the Sun himself occasionally yields to this supremacy, though the glory of his corona at such a time rivals the impressiveness of the Moon's achievement.

Being but a vassal monarch, her scope has its restrictions, and, unlike the erratic comet and the lawless meteor, there are tracts in the firmament where she has never been seen, for no combination of perihelion, perigee, and planetary interference can extend her variations beyond a certain limit.

Inside her allotted zone, her range, though complete, is methodical. For instance, near that point of the celestial sphere called the vernal equinox she may glide by the tail of *Cetus*, five degrees south of it, or by the *Western Fish*, five degrees north of it; but nine years must elapse between the times that she skirts these opposite edges of her roadway.

In like manner she may occult the *Pleiades* (as she has frequently done of late), but, in the meantime, the *Hyades* will glimmer in immunity from occultation to the end of the century.

This is owing to the fact that the angle of five degrees which the plane of the Moon's orbit makes with the plane of the ecliptic reverses its position in about nine years, three and a half months; for it lacks the greater permanence of direction of the planetary angles.

In each sidereal revolution, as seen on the heavens, she passes from a point on the edge of her zone obliquely inward for about ninety degrees, when she crosses the ecliptic, and continuing obliquely, reaches a point ninety degrees farther, which is on the opposite side of the celestial sphere, and also on a different edge of her zone.

Another curve inward of about ninety degrees brings her to the ecliptic again, which is recrossed nearly opposite to the previous intersection; and, generally, *before* the revolution is fully completed, the edge has again been reached, though somewhat west of the first point.

On account of different positions with regard to Earth and Sun, and her varying distance from these orbs, these specified divisions of her orbit are far from being exact quadrants, and are not apportioned equally to the quarters of her period of twenty-seven and one-third days, but have a tendency on the whole to be completed a few hours in advance of an entire circuit in Right Ascension.

Thus these points on the bounds of the lunar zone, and also the nodes or intersections with the ecliptic, are not the same in two consecutive revolutions, but are found in the course of a year to have moved about nineteen degrees westward, or in a direction contrary to the order of the signs. This movement, known as the retrograde motion of the nodes, results in a network of pathways which, for general conception, may be thought of as one and a half degrees apart, though in reality a wavering, irregular network, frequently tangled by the varying influence of gravity.

Two hundred and forty-eight revolutions and a period of six thousand seven hundred and ninety-three and one-third days are required to complete the reticulations from border to border along the zone; and then the complex but systematic wanderings are retraced with little variation.

This periodic repetition of her routes was more or less accurately known to the sages of antiquity, who gave the name of *Saros* to the eighteen-year cycle which brought a recurrence of eclipses in nearly the same part of the heavens.

These interesting phenomena, however, are incidents of her wanderings that lie outside the scope of this paper, which is designed only to call attention to the most noticeable results of the varying declinations* attained during a sidereal cycle of eighteen years and seven months. Those who are familiar with the imaginary circles of the celestial sphere, and with the relative positions of the celestial equator, and the ecliptic, or Sun's apparent path, will readily understand the effect of a change in direction of the angle of the Moon's orbit.

As the ecliptic crosses the celestial equator at an angle of twenty-three and a half degrees, about one-half is north of that circle, the most northerly part of the curve being in *Gemini;* and the other half south of it, the most southerly course being in *Sagittarius;* while the two intersections occur, respectively, in *Virgo* and *Pisces.*

In the following diagrams, which represent the most striking differences of position, the lunar path for ninety degrees on each side of the vernal equinox is supposed to be viewed from the center of the earth, as from that ideal standpoint of observation the obstructing horizon can be dispensed with.

The arrows show the direction of the Moon's motion.

For convenience of explanation, the present cycle may be dated from June, 1885, when the path held the position represented in diagram 1. At that time the north edge touched was that north of the most southerly curve of the ecliptic, and the south edge, south of its most northerly curve.

She descended in the vernal equinox where the ecliptic crosses above the celestial equator, and, at the opposite node, ascended in *Virgo*, where the ecliptic passes down. Consequently, her range was between the two circles, and her declination varied only from eighteen degrees north to eighteen degrees south, which points corresponded respectively with her most southerly and northerly latitudes.

Diagram 2 shows the result of the gradual change during the succeeding four years and seven to eight months. In February, 1890, the ascending node had then retrograded into *Gemini*, and the descending node into *Sagittarius;* while the extremes of Declination corresponded with the ecliptic angle, and lunar latitude five degress south was in *Cetus*, south of the vernal equinox, and five degrees north in *Virgo*, north of the autumnal equinox.

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* It may be necessary to remind the reader that the positions given are those the Moon would have if viewed from the Earth's center, as is customary, to avoid the conflicting effects of parallax.

Diagram 3 represents what may be called the climax of change when the ascending node is near the vernal equinox where the ecliptic passes above the celestial equator, and the highest point is in *Auriga*, a constellation rarely invaded by the lunar disk. On September 15th of the present year the Moon, then a few hours past full, crossed the ecliptic within 1° 35′ of the vernal equinox, and ranging north and east till September 22d, attained, as seen from the center of the earth, a declination of 28° 44′ 18″ when in $6^h\ 1^m$ Right Ascension. This was the highest declination and consequently the highest altitude attained during the present cycle.

As lunar wanderings are never abrupt, she was nearly as high in the heavens twenty-seven days previous, or on August 25th, when in North Declination 28° 40′ 19″, and also during the subsequent lunation, October 19th, when in Declination 28° 40′ 51″.

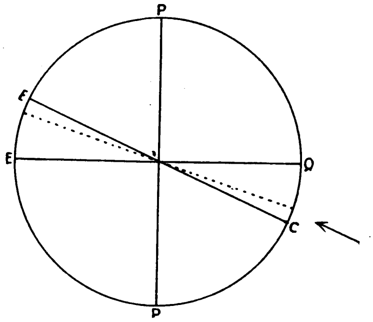
However, a few minutes of an arc are quite a measurable portion of the heavens and important in lunar distances.

The evening crescent of March 31st, 1876, visible in Europe, but obscured by sunlight to observers in America until it had been curving downward for several hours, had the highest declination of the last cycle; but as this was only 28° 43′ 29″, and consequently forty-nine seconds lower than that of September 22d, the waning half moon of that morning was farther north than our satellite had been in a period of more than thirty-seven years.

Being near the meridian of observers on the Pacific Coast, its high altitude was conspicuous and entailed altitudinal difficulties not often encountered when observing the moon in intermediate latitudes.

Before sunrise, as the silvery intruder dimmed the lights of the *Charioteer* and glanced on the California coast through a less depth of atmosphere than for many years before, a telescopic observation of its surface was taken at the choice moment of highest altitude.

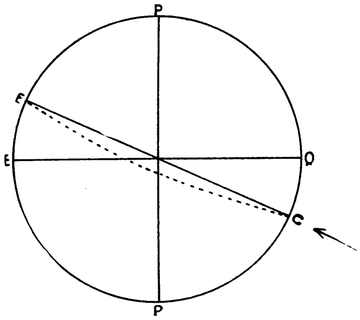
The libration in latitude, then at its maximum, revealed the rugged southern tracts far beyond *Tycho*, while the northern limb was unusually near *Plato*, and the Alpine peaks projecting into sunlight. It is to be hoped that the unique outlines and



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1885.

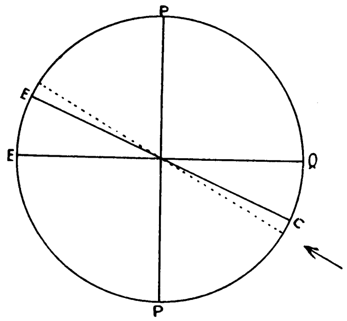
DIAGRAM 1.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1890.

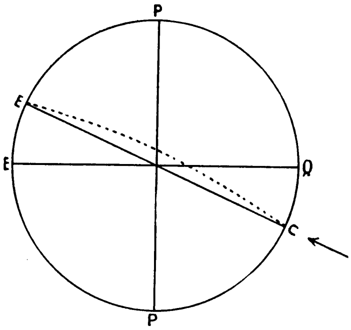
DIAGRAM 2.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1894.

DIAGRAM 3.



P P, Poles. E Q, Equator. E C, Ecliptic.

DOTTED LINE, MOON'S PATH, 1904.

DIAGRAM 4.

shadows of that hour have been preserved for future comparison by means of the camera.

As shown in Diagram 3, when the Moon's most northerly latitude corresponds with its most northerly declination, the most southerly latitude will be also attained about the same time as the most southerly declination.

Accordingly, on October 5th, less than two weeks from the date of highest altitude, the phase near first quarter when in R. A. $18^h\ 1^m\ 54^s$ had a South Declination of 28° 43′ 39″, a more southerly range than had been attained since March 17, 1876. Eight hours later it was on the meridian of Pacific Coast observers, glimmering like a gauntlet on the outstretched arm of the *Archer*, instead of forming his shield or helmet, as usual.

As the libration in latitude on this occasion revealed the north polar regions, such inconspicuous craters as *Scoresby*, *Meton*, and *Euctemon* were distinctly noticeable within the terminator which curved by the *Sea of Serenity*, skirted the complexities of *Stöffler* to the south, and joined the limb, leaving some well-known south polar summits on the other side of the moon.

As explained above, a near approach to the extremes of declination is also made in previous and subsequent lunations. The waning, gibbous Moon of September 8th and the crescent of November 1st were within nearly one minute of an arc of the same southerly position.

But the waning half moon of March 17, 1876, was forty-four seconds farther south, a declination that cannot again be equaled until the spring of 1913, and perhaps not even then.

Thus, in the present lunar cycle, the highest North Declination was attained, while in the last cycle the southward curve exceeded it by about five seconds of an arc, the difference being due to slight variations in the angle that the Moon's path makes with the ecliptic, and to a difference in Right Ascension. In 1899 the most northerly and southerly declination shall again have decreased to that of the ecliptic in *Gemini* and *Sagittarius;* but, as shown in Diagram 4, the ascending and descending nodes shall have exchanged the positions held in 1890, and the path shall curve above instead of below the vernal equinox.

In 1904, the intermediate position shown in the first diagram shall be resumed, and the cycle completed. As the extremes of declination described above were not coincident with full moon either in the past or present cycle, it will be of interest to note the highest and lowest declination of that conspicuous phase.

The lunar tables show that the full moon of December 30, 1876, when in R. A. $6^h 43^m$ had a North Declination of 27° 36′ 7″. It shone from the zenith of Egyptian lands, but was probably of equal radiance a few hours later when at perigee and on the meridian of the Southern States of North America.

But the full moon of December 22, 1893, R. A. $6^h 6^m$, was still higher, having a Declination of 28° 17′ 25″; and being only half a degree past perigee, was in a better position for light-giving on mid-Atlantic north of N. latitude 28° than at any time within thirty-seven years. This increase of light is not merely theoretic, as the apparent size of the disk increases as the square of the apparent diameter; and with a combination of high altitude and perigee seems one-fourth larger than when near the horizon and at its greatest distance.

To Pacific Coast observers it had a medium altitude north of east. When on the meridian a few hours later, and several seconds lower in declination and a few degrees past perigee, it was one of the brightest full moons of this cycle. No doubt many who chanced to look out at midnight wondered at the distinctness of the landscape.

On the seashore, where the atmosphere is apt to frustrate its illuminating powers, the decrease of distance was otherwise evinced; for its attractive forces never fail to leave their record on the surging wave. Before many hours elapsed the waters had rippled farther in than usual along the Pacific Coast from San Diego to Alaska, and according to the predictions of the tide-tables, the increased range was not fully equaled for more than a year.

At such times many rush-grown tracts, for years watered only by rain and fog, are reclaimed by the ocean under the guiding rule of the perigean Moon.

The sound of the waves are thus as truly the music of the spheres as if waked by a visible touch from ethereal heights.

The voice of an unwonted tide, whether it whispers of the Moon's approach among the rushes, or roars the tidings on the high cliffs, is the most impressive of all the voices of inanimate nature.

The recent shipping disasters were no doubt largely due to the increase of lunar influence on the atmosphere and waters beyond semi-tropical regions; for the life experience of a mariner is not sufficient to familiarize him practically with the possibilities of the eighteen-year cycle.

During a period of about three years in each cycle, the spring tides of summer, and more especially those of winter, roll in beyond their wonted bounds very noticeably, and occasionally the perigean tide, with conspiring winds and currents, brings ruin in its path.

Those who understand the causes of the two daily tides and their variations can readily call to mind the necessary effect of an increase of declination when the new or full moon is in perigee. Persons who have had continual opportunity of noticing ships in port can generally recall at least one period when the hulls were visible high above the usual level, and in some cases in the plane of the partly submerged wharf.

In the tide-tables of the year 1876 the predicted range of the winter perigean tides from higher high to lower low was one foot and three-tenths less than that of December 23, 1893, at the port of San Francisco.

Using this port as a gauge, we find from *Davidson's Coast Pilot* that the average difference between higher high and lower low in consecutive hours is five and two-tenths feet. Consequently, the predicted range on the above date being eight and one-tenth feet was nearly three feet beyond the average.

A range of two and three-tenths feet beyond the average was predicted for the twelve hours succeeding the full moon of December 12, 1894, and a range as great as three and two-tenths for January 10, 1895. The difference in the three ranges may be traced to more or less effective combinations of favorable conditions.

The learned professor, to whose official labors in the interests of navigation the public are indebted for the valuable book above named, has courteously furnished to the writer the tidal data and and further explained that the grade of the ocean-bed, the interference of currents and winds, and the influences of climate are important factors in tidal effects, and sometimes create a difference between the table of predictions and the observed range.

The full moons that hung low down in the midnight summer skies were not such effective tide-raisers during either cycle as the same phases in winter, but their characteristics were equally distinct.

In northern countries they rose in the southeast late in the evening, and seemingly of unwonted size, shone for a few hours in picturesque proximity to the southern landscape, a striking verification of the law that "in summer, when the Sun runs highest, the full moon runs lowest."

The beautiful orb of June 17, 1894, was somewhat lower than the most southerly Moon of 1876.

When the occultation of stars is considered, even a few seconds of an arc are an important difference. The starry pathway being slightly different in successive revolutions, the various occultations are a conspicuous and interesting effect of lunar wanderings.

From time to time each of the major planets is cut off from view by the roving satellite of the Earth, but *Mercury* alone is ever encountered in the extremes of lunar latitude or Declination. *Aldebaran*, *Regulus*, *Antares*, *Spica*, the only stars of first magnitude within five degrees of the ecliptic, are generally occulted during each cycle to observers in some part of the Earth, for, on account of parallax, occultations depend on the latitude and longitude of observers. When, at long intervals, it is found that such stars as 49 and 54 *Auriga* and *e* and *Gamma Sagittarius* have been occulted, perhaps, a few times in succession, it is evidence that the queenly orb has speeded around the most northerly and southerly confines of her sidereal realm.

Like milestones the stellar lights mark her progress along the winding interlacing journey of years' duration which ends only to be re-commenced again and again for endless ages.

SAN FRANCISCO, CAL.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1895.

BY PROFESSOR MALCOLM MCNEILL.

NOVEMBER.

Occultations. The Moon passes over the *Pleiades* twice, on November 3d in the early evening, and again on the night of November 30th, or rather, early in the morning on December 1st. On November 3d the Moon is just past full and the immersions will be at the bright limb and the emersions at the dark limb. The occultations at the end of the month occur just before the Moon is full, and the immersions will be at the dark limb. The